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Research opportunities in production engineering: a diagnosis instrument proposal

Oportunidades de pesquisa em engenharia de produção: uma proposta de instrumento de diagnóstico

Recebimento dos originais: 01/05/2018
Aceitação para publicação: 07/06/2018

Isabela Felix Moreira Neves
Graduada em Engenharia de Produção pela Universidade Federal de Itajubá (Unifei)
Instituição: Universidade Federal de Itajubá, câmpus de Itabira (MG)
Endereço: Rua Irmã Ivone Drumond 200 – Distrito Industrial, Itabira - MG, Brasil
E-mail: isa.fmn@gmail.com

Tassiana Vale D'Elboux
Graduada em Engenharia de Produção pela Universidade Federal de Itajubá (Unifei)
Instituição: Universidade Federal de Itajubá, câmpus de Itabira (MG)
Endereço: Rua Irmã Ivone Drumond 200 – Distrito Industrial, Itabira - MG, Brasil
E-mail: tassivale@hotmail.com

Sandra Miranda Neves
Doutora em Engenharia de Produção pela Universidade Estadual Paulista (Unesp)
Instituição: Universidade Federal de Itajubá, Instituto de Engenharia de Produção e Gestão (IEPG), Itajubá (MG)
Endereço: Av. BPS, 1303, Bairro Pinheirinho, Itajubá - MG, Brasil
E-mail: sandraneves@unifei.edu.br

Emerson José de Paiva
Doutor em Engenharia Mecânica pela Universidade Federal de Itajubá (Unifei)
Instituição: Universidade Federal de Itajubá, câmpus de Itabira (MG)
Endereço: Rua Irmã Ivone Drumond 200 – Distrito Industrial, Itabira - MG, Brasil
E-mail: emersonpaiva@unifei.edu.br

Janaina Antonino Pinto
Mestre em Engenharia Civil pela Universidade Estadual de Campinas (Unicamp)
Instituição: Universidade Federal de Itajubá, câmpus de Itabira (MG)
Endereço: Rua Irmã Ivone Drumond 200 – Distrito Industrial, Itabira - MG, Brasil
E-mail: janainaantonino@unifei.edu.br

ABSTRACT

The University-Industry Relationship presents itself as an important factor for the socio-economic development, whether municipal, regional or national. So the goal of this article is to propose an instrument for the diagnosis of research opportunities in Production Engineering in the commercial

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sector at the Brazilian city of Itabira (MG). The research method was the theoretic-conceptual, through a bibliometrics analysis, obtained on the basis of Web of Science. Articles were assessed from knowledge areas required by the Brazilian Association of Production Engineering (ABEPRO) and published in 2014 and 2015. The diagnostic instrument was drawn up from a bibliometrics analysis and validated by experts' opinion, professors from Federal University of Itajubá (UNIFEI). A pilot test has also been accomplished with four companies, members of an Association of Itabira. As the main result, the test has indicated that the priority area for research is the Economic Engineering in the commercial sector of Itabira.

Keywords: Production Engineering; Commercial sector; University-Industry relationship; Bibliometrics.

RESUMO

O Relacionamento Universidade-Indústria apresenta-se como um fator importante para o desenvolvimento socioeconômico, seja municipal, regional ou nacional. Assim, o objetivo deste artigo é propor um instrumento para o diagnóstico de oportunidades de pesquisa em Engenharia de Produção no setor comercial da cidade brasileira de Itabira (MG). O método de pesquisa foi o teórico-conceitual, através de uma análise bibliométrica, obtida com base no Web of Science. Os artigos foram avaliados a partir de áreas de conhecimento exigidas pela Associação Brasileira de Engenharia de Produção (ABEPRO) e publicados em 2014 e 2015. O instrumento diagnóstico foi elaborado a partir de uma análise bibliométrica e validado pela opinião de especialistas, professores da Universidade Federal de Itajubá (UNIFEI) . Um teste piloto também foi realizado com quatro empresas, membros da Associação de Itabira. Como principal resultado, o teste indicou que a área prioritária para pesquisa é a Engenharia Econômica no setor comercial de Itabira.

Palavras-chave: Engenharia de Produção, setor Comercial, relação Universidade-Indústria, Bibliometria.

1 INTRODUCTION

Itabira (MG) is a center of production and consumption of goods and services with an economic, social and cultural nature. Known as the poet Carlos Drummond de Andrade's birthplace, and headquarters of one of the biggest mining companies in the world, the Vale company, its importance goes beyond: according to data from Geographic and Statistics Brazilian Institute (IBGE, 2015), Itabira is the municipality with the largest Gross Domestic Product (GDP) in Minas Gerais state.

There is, installed in the municipality, a significant amount of micro and small enterprises. According to the Commercial, Industrial, Services and Agricultural Association of Itabira, from the total of associated companies (323), 205 belong to the commercial sector, representing a 63% portion (Acita, 2016).

Economic growth depends on the creation and exploitation of knowledge. Provided by the universities, the advancement and creation of new techniques, if transferred to the commercial sector, help to innovate and survive in today's market (Lorentzen, 2015). In 2008 it had been held a public-private partnership among the city of Itabira, the mining company Vale, the Ministry of Education and the Federal University of Itajubá (Unifei), so it was possible the creation of a new Campus in Itabira. At this Campus, the Production Engineering course has been searching for a differentiate approach in relation to the more than 350 universities, providing such a course in Brazil (Folha de São Paulo, 2014). In addition to the mechanical emphasis, there has been a stimulus to practical activities, as well as the focus on innovation and entrepreneurship.

According to the Brazilian Association of Production Engineering (Abepro, 2012), the Production Engineering includes the following operating areas: Operation and Processes Production Engineering, Logistics, Operation Research, Quality Engineering, Product Engineering, Organizational Engineering, Economic Engineering, Working Engineering, Sustainability Engineering and Educational Engineering. The Educational Engineering area reflects issues related to the development and insertion of Superior Education in Production Engineering. This one, however, won't be reviewed in this article, once it isn't applicable to the commercial sector.

One can see all these areas as different opportunities for research, as they can be individually reviewed, or relate them to each other. In addition, they require specific knowledge and skills that exist at the academy and offered by UNIFEI to the community at large, as they are available. Once there is a demand from the community and that knowledge and skills are available, the insurgent doubt is: what are the issues, related to the knowledge areas in Production Engineering (PE), are priority for the companies from the commercial sector of Itabira?

Trying to answer this question, it has been proposed, in this research, the development of an instrument to diagnose what kind of transfer, from the PE knowledge areas, are priorities for the companies from the commercial sector of the city of Itabira (MG). To do so, it has taken some activities: to identify the main area, in PE knowledge, to draw up a bibliometrics analysis, taking into account the knowledge areas and to develop the research tool, based on the bibliometrics analysis and experts' opinion.

The article is structured as follows: section 1 presents the introduction, involving the justification for carrying out the research, the research question and objectives; section 2 covers the theoretical framework; section 3 presents the methodological procedures; section 4 covers the

results and discussions and, finally, section 5 presents the research findings, limitations and suggestions for future survey.

2 THE CREATION OF KNOWLEDGE IN THE UNIVERSITY-COMPANY PARTNERSHIP

The knowledge management is a field that assists in the knowledge and creation process, related mainly to information, technology and innovation (Madeira, Vick and Nagano, 2013). To minimize earlier forms of privatization, in the early 80s, it began developing partnerships between the private and public sector (Robertson and Verge, 2012) with the introduction of public-private partnerships (PPP) for different nature problems solution. PPP is "as long term contract between a private part and a government agency, to provide a public benefit or a public service, where the former is the responsible for risks, as well as for the management" (World Bank Institute, 2012, p 11).

The relationship between the Company, Government and University is important for the social-economical process, mainly in the current scenario. This relationship has been defined in the halfway of the 90s decade as the triple helix, a pivotal factor for the 20th Century new innovation strategies (Etzkowitz and Leydersdorff, 1955; Luengo and Obeso, 2013).

Among the three actors of the triple helix their responsibilities and limitations are different in the existing relationship. The main incentive for the University is the acquisition of financial resources for educational and survey projects, besides a possible working possibilities for the students. On the other hand, the motivation for industry is to have access to the infrastructure and knowledge of the universities, aiming to expand the current technology, increasing its competitiveness (Chang and Hsu, 2002).

3 MATERIALS AND METHODS

The nature of the used research method was a theoretical-conceptual (Miguel, 2010), which is "the production reflections from a phenomenon observed or reported by literature (bibliographical review), ideas and opinions compilation from different authors or even simulation and the theoretical modeling" (Berto and Nakano, 1998). It has been used, as a tool for structuring data for analysis, the bibliometrics technique. According to Araújo et al. (2000), this kind of study aims to observe the literature evolution and the knowledge produced over the years. The research covers the period from 2014 January to 2015 October, for the purpose of obtaining the latest articles.

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Initially, in order to find the latest articles with topics related to every subarea based on Web of Science, a research has been carried out using words related to those PE areas. Table 1 shows the identified articles amount.

Table 1 - Identified publications based on Web of Science data.

Area	Number of publications	Area	Number of publications
Operation and Processes Production Engineering	898	Organizational Engineering	348
Logistics	442	Economic Engineering	860
Operational Research	364	Working Engineering	567
Quality Engineering	230	Sustainability Engineering	635
Product Engineering	602		

After obtaining the data, one used the program VOSviewer to build and show the bibliometrics connections. This software did a survey of the most used words in the abstract and titles of the articles. For obtaining the Bibliometrics it has been considered the binary terms repeating at least 7 times. The software itself calculates the relevance of these terms, selecting only the 60% more important. So, through this procedure, it has been generated a map, containing the most cited terms. The terms highlight is proportional to the number of the terms repetition. The lines and colors show the relationship between them.

The interaction among the researchers and community occurred from a questionnaire. This questionnaire is a tool that helps the researchers to identify perceptions, expectations and opinions in several areas (Ergang et al., 2012). This diagnosing tool has, as its main goal, “to translate the needs of information of the researcher in a specific set of issues, the respondents are willing and able to respond” (Malhotra, 2009). This issues can be of open or closed type.

With regard to the analyses of the closed answers, they can transform into quantitative data, through the definition of scales. Some of the more used scales are: Likert Scale, numeric and Guttman (Tractenberg et al., 2012; Bertram, 2013). As soon as the kind of question is chosen, the result modeling analysis should, the best way, read the collected information. In the present scales, the main one, and most used for closed question, in the Likert Scale, the one used in this survey.

4 RESULTS AND DISCUSSION

This section shows the results from the theoretical-concept analysis for two of the areas in PE (Operational Research and Quality Engineering). Based on the characteristics of each area, it has been used the Bibliometrics technique for obtaining primary data from the research tool. The

analyses were carried out in conjunction with experts, incorporated entirely by professors. These analyses allowed the validation of the obtained results.

4.1 OPERATIONAL RESEARCH

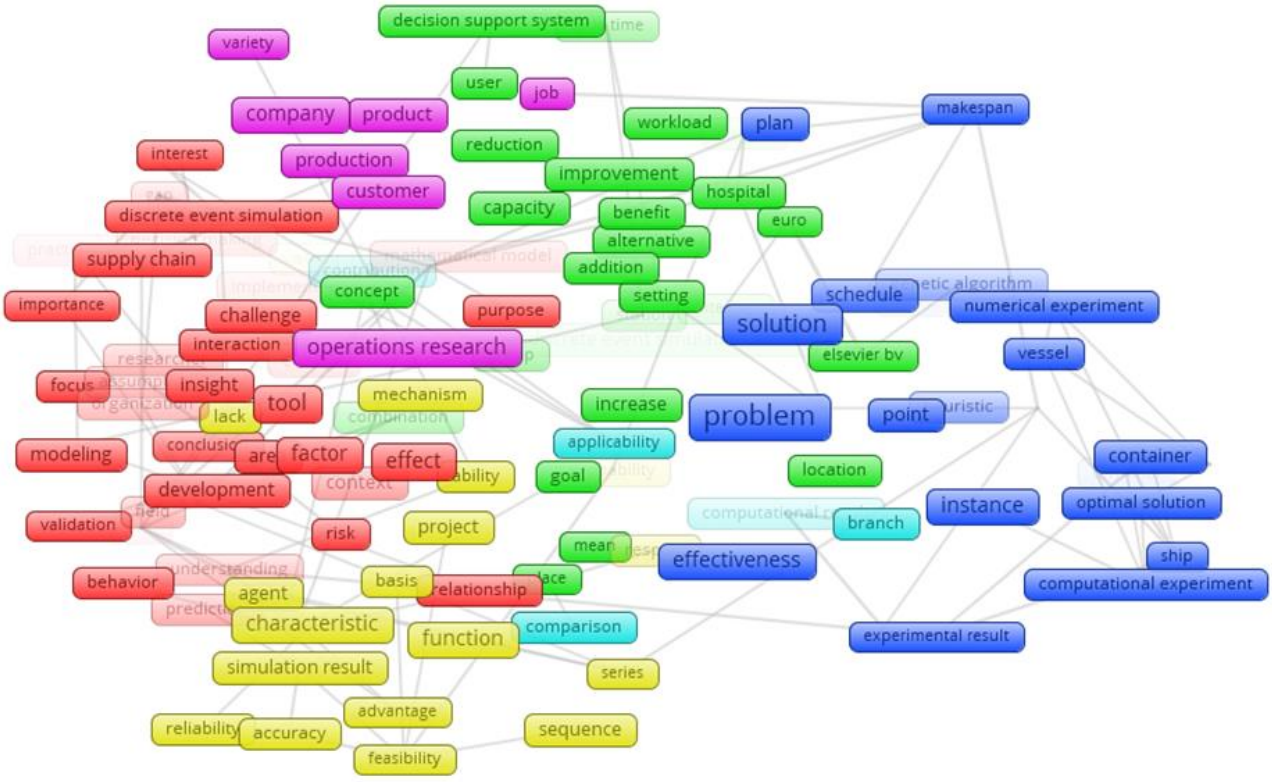
Performing the procedures described in Bibliometrics (section 3), one obtained the Table 2 data.

Table 2 - Values obtained in bibliometrics of Operational Research area

Articles found	**Terms found**	**Binnary terms repeated at least 7 times**	**Terms with at least 60% of relevance**
364	9.067	209	125

Figure 1 shows the map provided by the software with the most cited terms.

Figure 1 - Cloud of most recurrent terms in Operational Research.



It has been carried out some inferences with the words that appear the most (Table 3).

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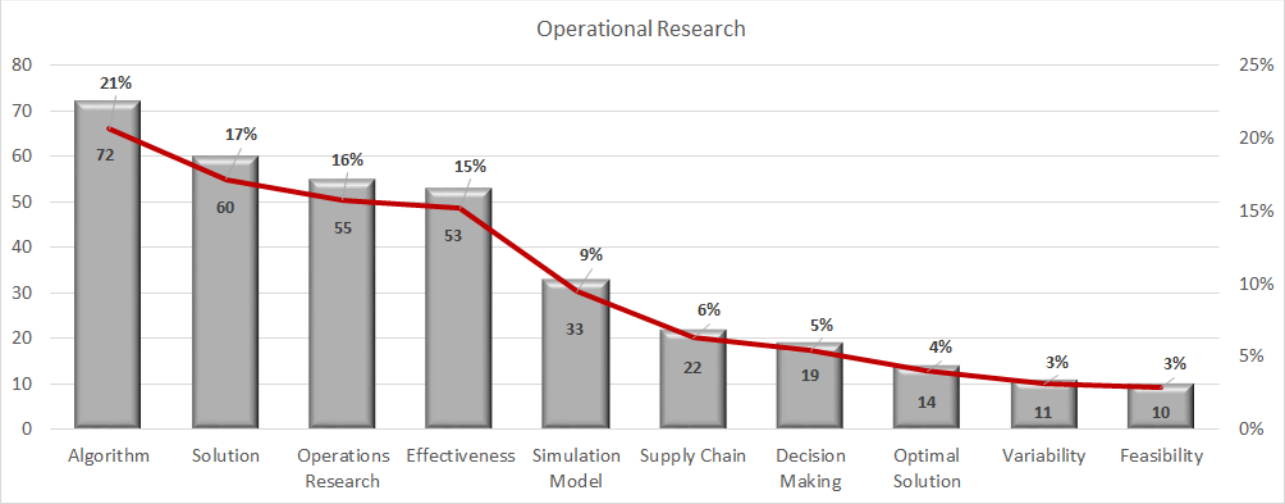
Table 3 - Recurring terms in the Operational Research, as defined by experts.

Terms	Expert Description
Algorithm	Conditions and procedures for limitation of mathematical systems troubleshooting.
Solution	Problem solving, uncertainties and difficulties
Operational Research problem	Production area involving problem drafting of mathematical models for solving and support of decision-making forms.
Effectiveness	Every model should have its effectiveness proven.
Simulation model	Mathematical abstraction (or graphic), which allows different scenario to be generated and tested, without interference in the real system.
Supply chain	Many supply scenarios are reviewed using mathematical models.
Decision-making	Operations research model provide data and values that generally are used to assist in decision-making.
Optimal solution	The best solution for a given problem.
Variability	It indicates the ability to respond to changes.
Viability	Used to refer to solutions and/or viable implementation models.

Figure 2 shows the themes of higher occurrence, according to the results obtained by the VOSviewer software and the prioritization by the experts.

Figure 2 - Chart of terms of higher occurrence in Operational Research.



According to the analysis, the graphic, the image map and considerations by the experts, four questions arose for the questionnaire. These questions can be viewed in Appendix A (issues from 11 to 14).

4.2 SUSTAINABILITY ENGINEERING

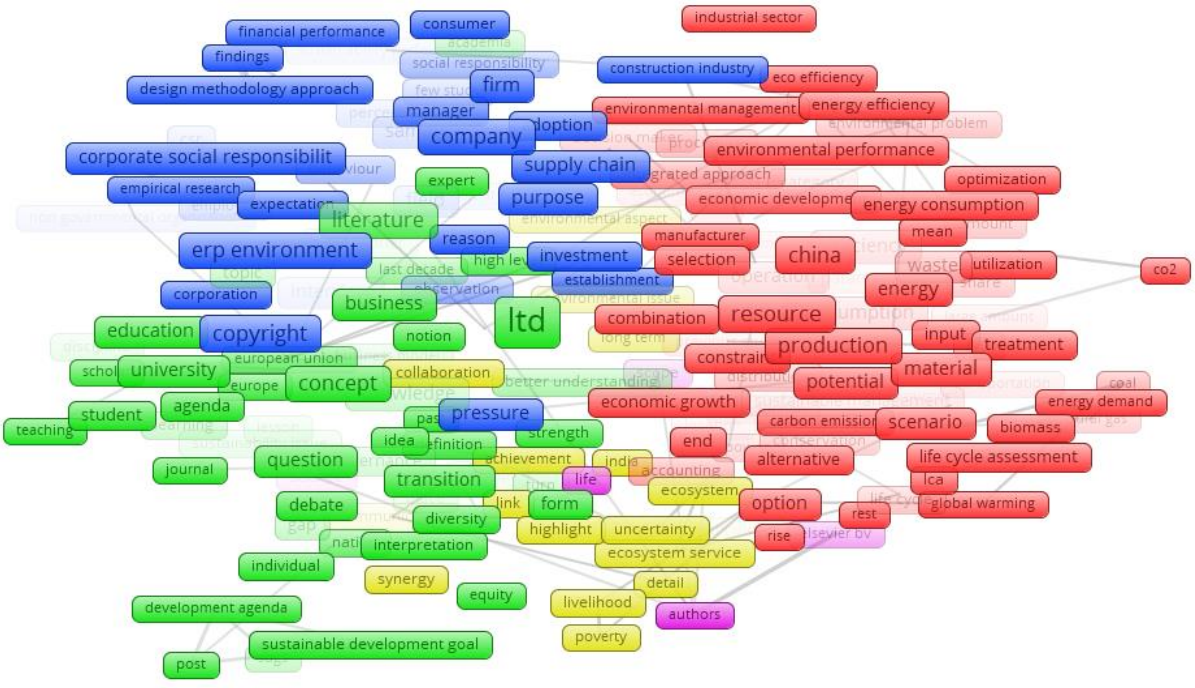
With respect to the Sustainability Engineering area, the data obtained are shown in Table 4.

Table 4 - Values obtained in bibliometrics of Sustainability Engineering area

Articles found	**Terms found**	**Binnary terms repeated at least 7 times**	**Terms with at least 60% of relevance**
635	15.432	506	304

Figure 3 shows the map provided by the software with the most cited terms.

Figure 3 - Cloud of most recurrent terms in Sustainabilty Engineering.



Based on Figure 3, some inferences were carried out, related to recurring terms (Table 5).

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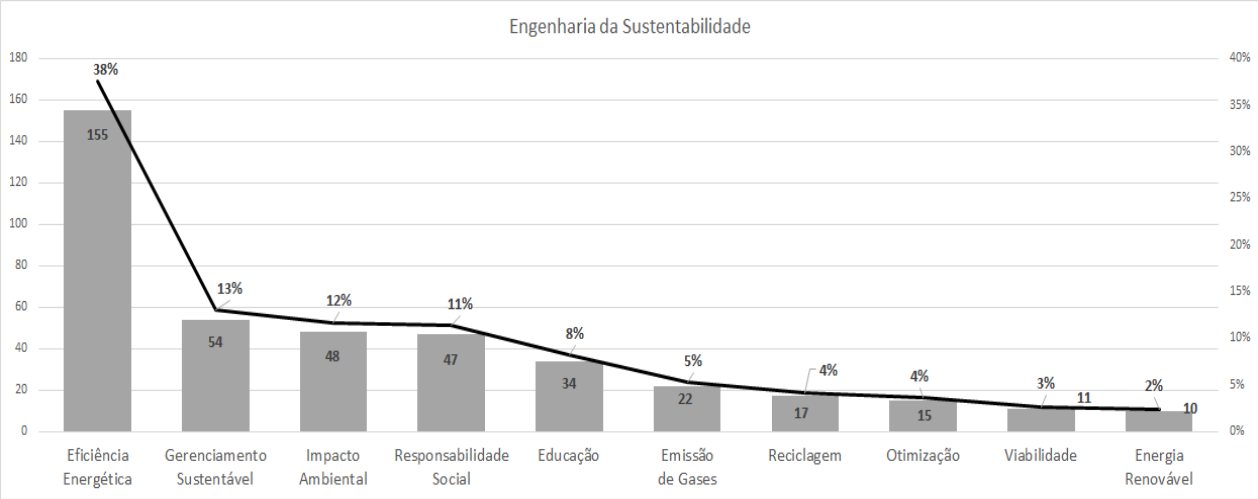
Table 5 - Recurring terms from the Sustainability Engineering area, according to the definition by experts.

Terms	**Expert Description**
Energy efficiency	Get the best performance of a product or service using less energy
Susainable Management	Management of the relationship and the impact involved between society and the environment
Environmental impact	Effects provided by human activities on environment
Social responsability	Commitment of the society and the company to keep the environment in balance
Education	Correct habits of the use of energy sources and basic features without losing comfort
Gas Emissions	It is related to climate changes that have been taking place on Earth, partly it is because of the growth of CO2 emissions
Recycling	Make a product ready for use again
Optimization	Maximize results
Viabiliy	Activity or product that has features for execution
Renewable energy	Energy sources that use clean technologies and practices, namely sustainable

Figure 4 presents the themes of higher occurrence, according to the results generated by the VOSviwer software and the priorization by experts.

Figure 4 - Chart of terms of higher occurrence in Sustainability Engineering.



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According to the analyses, the chart, the image map and the expert´s considerations, 5 questions were considered for the questionnaire. The questions are shown in Appendix A and they represent the questions from 43 to 47.

4.3 QUALITY ENGINEERING

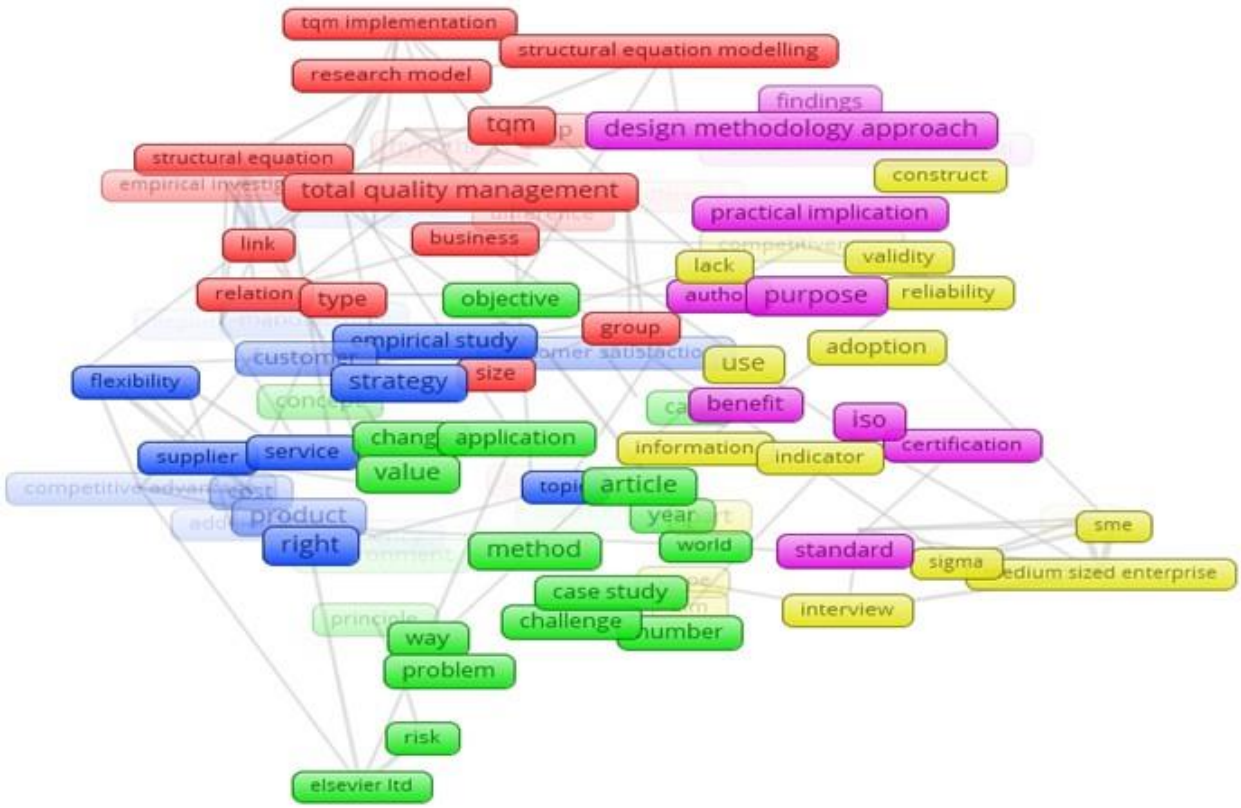
With respect to the Quality Engineering area, the data obtained are shown in Table 4.

Table 6 - Values obtained in bibliometrics of Quality Engineering area

Articles found	**Terms found**	**Binnary terms repeated at least 7 times**	**Terms with at least 60% of relevance**
230	5.193	192	115

In Figure 3 one can see the map, provided by the software, containing the most cited terms.

Figure 5 - Cloud of most recurrent terms in Quality Engineering.



Based on Figure 3, some inferences were carried out, related to recurring terms (Table 5).

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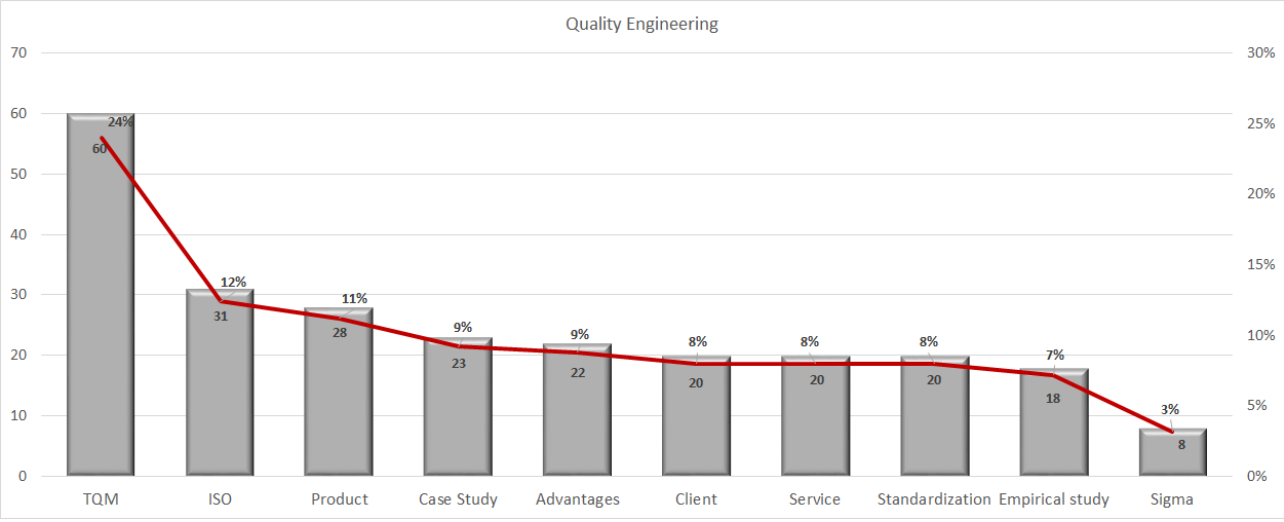
Table 7 - Recurring terms from the Quality Engineering area, according to the definition by experts.

Terms	Expert Description
Total Quality Management (TQM)	They are strategies used by companies to develop a cultural quality related to their processes and services. They cover the practices, impacts, models, tools, systems, performance evaluation, among other subjects.
ISO	Regulatory models are still the focus of important researches. Many studies report the benefits of certifications (covering, for example, the periods of before and after).
Product	Jobs that involve evaluation quality in products/services. This term reflects the importance of quality planning in the product development.
Case study	Indication that lots of research in this area use the case study method.
Advantages	It may involve the benefits of implementation of quality improvement methods (there is also a lot of research regarding the advantages and disadvantages of some methods, applications, and so on).
Client	One of the goals of the implementation of quality/process is to enable customer´s satisfaction (costumer´s focus is a fundamental principle of quality management).
Service	The service sector is always registering a growth over the years. It becomes, therefore, an important target of study (which is the matter of the survey portrayed in this article). The evaluation of quality in services is also a relevant theme.
Standardization	It involves the development and implementation of standards. It is also one of the main benefits of certifications, helping in the organization of companies and an important managerial tool.
Empirical study	Those studies that are based on practical application and living experiences.
Sigma	Publications on this theme usually consist of articles that use this methodology to determine and mitigate the variability of process or concerning the management and selection of the projects.

Figure 4 presents the themes of higher occurrence, according to the results generated by the VOSviwer software and the priorization by experts.

Figure 6 - Chart of terms of higher occurrence in Quality Engineering.



According to the analyses, the chart, the image map and the expert´s considerations, 7 questions were considered for the questionnaire. The questions are shown in Appendix A and they represent the questions from 15 to 21.

The bibliometrics analysis and the assessment of experts were carried out for all the knowledge areas (Operation Engineering and Production Processes, Logistics, Product Engineering, Organizational Engineering, Economical Engineering, Working Engineering, Sustainability Engineering). The result of this analysis was include in the obtained research instrument (Appendix A).

4.3 PILOT TEST RESULT

The questionnaire was sent, in October 2015, to 8 (eight) commercial sectors companies of Itabira. For a better understanding, an elaborate description for each term has been carried out. 4 (four) companies replied the questionnaire by electronic means, using the QuestionPro, which is a world reference in softwares used in surveying. Figure 5 includes, on the *y* axis of each graph, the average interest for topics in each area (corresponding to 47 issues). The maximum grade of interest corresponds to 5 (five).

Based on the answers of the pilot test, it was possible to spot the interest in researches of PE areas, according to the group average, being: 1- Economical Engineering (3.45); 2- Organizational Engineering (3.25); 3- Operation and Production Processes Engineering (3.05); 4- Logistics (2.90); 5- Operational Research (2.88); 6- Sustainability Engineering (2.80); 7- Quality Engineering (2.79); 8- Product Engineering (2.70); 9- Working Engineering (2.70).

With respect to research topics of the greatest interest, the 8 (eight) first in order were: 1- Perform indicators (3.75); 2- Cost management (3.75); 3- Evaluation of the provided services quality (3.5); 4- Strategic and organizational management (3.5); 5- Human Resources management (3.5); 6- Risks analysis (3.5); 7- Pricing (3.5); 8- Financial Market structure (3.5).

In the case of other certification types (question 21), none of the companies displayed interest in other types of certification in addition to ISO 9001.

Regarding the matters relating to the companies interest to offer internship for PE course students (questions 48 and 49) only half of them showed interest in hiring PE trainees.

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Those that showed interest rated their priorities in accordance with the following areas: Quality Engineering, Logistics, Economical Engineering, Operation and Product Processes Engineering, Product Engineering, Sustainability Engineering, Working Engineering, Operations Research and Organizational Engineering.

Figure 5 - Levels of interest in accordance with themes of the Production Engineering areas

The operators also got in touch with the companies for a more careful evaluation. The final questionnaire can be viewed in Appendix A.

5 CONCLUSION

This article had, as its main goal, to develop an instrument to diagnose what types of knowledge transfer, in PE areas, are priorities for companies from the commercial sector of the city Itabira (MG). The identification of the main knowledge area in PE, the preparation of bibliometrics analysis and the experts' opinion allowed, this way, this goal to be reached.

The pilot test provided the level of question understanding to be evaluated, as well as the research instrument improvement. It also provided the acquisition of some preliminary analysis (and limited to the number of respondents): The Economical Engineering, as the group of the greatest research interest, the interest of companies (50%) to offer internships and the themes Performance Indicator and Cost Management as the greatest interest of the companies.

This research belongs to an Opportunities Research Identification Project at the commercial and Industrial sector in the city of Itabira that, as results, intends: to stimulate skills related to the development of a research and the practical application of knowledge, to identify possible PE research areas, a higher knowledge and interaction with the local economy and identification of possible internship units' grantors.

The research instrument application will provide, this way, the knowledge exchange between the Faculty Board and the University students with the companies of the commercial sector of the city, allowing the sharing of experiences that can be enriching for all of them.

With respect to the elaborated research instrument, some limitations can be listed: data collection for Bibliometrics analysis in only one database (however, it is a sufficiently comprehensive database); each EP area has been evaluated by only one expert (it's possible that any expert can accomplish different inferences in the generated maps from the Bibliometrics analysis). Due to limitations of the text, only the most cited words have been included; however, all the other words have been reviewed, also being important sources for research and inference. Despite the described limitations, this work allows the strengthening of the University-Company relationship, as well as it allows to relate the PE areas with the reality of the city of Itabira.

It is suggested, for a future research, the application of the questionnaire at other cities with EP courses and that would like to identify research opportunities to improve the University-Company relationship.

ACKNOWLEDGEMENTS

The authors need to express their acknowledgements to FAPEMIG, Commercial, Industrial, Services and Agricultural Association of Itabira (ACITA) and all interviewees.

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APPENDIX A - Questionnaire

Identification of research opportunities in Production Engineering

This questionnaire is part of a project that aims to strengthen a University and the Commercial Sector relationship in the city of Itabira. So, the diagnose instrument will make possible the identification of possible research in the commercial sector and the analysis of the interest of the company to offer an internship. The series is divided in 11 parts, involving the main Production Engineering performing area. The main question involving the questionnaire is: **What's your interest in deploy/perform researches about the following issues in your company?**

The answer may vary on a scale of 1-5, where:

1	**2**	**3**	**4**	**5**
No interest	Future interest	Interest	Much interest	Extreme interest

	1. OPERATIONS ENGINEERING AND PRODUCTION PROCESSES					
Nº	Theme	Scale				
		1	**2**	**3**	**4**	**5**
1	Production Control System					
2	Layout					
3	Performance indicators					
4	Inventory control					
5	Management tools and techniques					
	2. LOGISTICS					
6	Supply chain					
7	Partnership reliability					
8	Transport logistics					
9	Warehousing and stock handling					
10	Lead Time					
	3. OPERATIONAL RESEARCH					
11	Decision-making tools					

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12	Simulation					
13	Optimization					
14	Demand forecasting					
	4. QUALITY ENGINEERING					
15	Total Quality Management – TQM					
16	5S program and other improving programs (like Benchmarking)					
17	Quality evaluation of provided services					
18	Seis Sigma.					
19	Metrological Equipment Quality					
20	ISO 9001 Certification					
21	Would you have interest in other certifications? ( ) I have interest in another certification. Specify.: ( ) I don´t have interest in other certtifications					
	5. PRODUCT ENGINEERING					
22	Product/Service Planning and Project					
23	Product/service Development Management					
24	Clients needs identification tools					
25	Used tools in product/service development process					
26	Product/services reliability analysis					
	6. ORGANIZATIONAL ENGINEERING					
27	Knowledge Management					
28	Information Management					
29	Strategic and Organizational Management					
30	Human Resources Management					
31	Projects Management					
32	Technology and innovation					
	7. ECONOMIC ENGINEERING					
33	Investment feasibility analysis					
34	Cost Management					
35	Risks analysis					
36	Pricing					
37	Market financial structure					
	8. WORKING ENGINEERING					
38	Muscleskeletal illness					
39	Working enviroment analysis					

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40	Ergonomic working stations conditions					
41	Deployment study breaks					
42	Laboral working gymnastics					
	9. SUSTANABILITY ENGINEERING					
43	Energetics efficiency					
44	Renewable energies - solar and wind power					
45	Smart grid					
46	Water rational use					
47	Waste Management					

	10. THE INTERNSHIP IN YOUR COMPANY		
Nº	Question	Scale	
		Yes	No
48	Would you be interest in hiring interns from UNIFEI/ITABIRA Production Engineering course in your company?		
49	Is so, number the interest areas according to your preference (1-Higher preference): ( ) OPERATION ENGINEERING AND PRODUCTION PROCESSES ( ) LOGISTICS ( ) OPERATIONAL RESEARCH ( ) QUALITY ENGINEERING ( ) PRODUCT ENGINEERING ( ) ORGANIZATIONAL ENGINEERING ( ) ECONOMIC ENGINEERING ( ) WORKING ENGINEERING ( ) SUSTAINABILITY ENGINEERING		